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ABSTRACT

This paper discusses the styles of computer-based learning and computer-based training in terms of their fundamental characteristics, including balance of control between program and learner, and the kinds of learning activity they induce. Learning and training are not considered to be intrinsically different in practice, and styles such as drill-and-practice, tutorial, simulation, and modelling are discussed with reference to both. Descriptions of current implementations of each of these styles include a critique of their advantages and disadvantages: (1) TICCIT (Time-Shared Interactive Computer-Controlled Television); (2) Educational Technology Center, University of California at Irvine; (3) CAISMS (Computer Assisted Study Management System), University of Illinois; and (4) the LOGO Laboratory, Massachusetts Institute of Technology (MIT). In conclusion, the likely educational potentials of the new media are considered, and an appropriate model for courseware development is suggested. (26 references) (Author/EW)

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STYLES OF COMPUTER BASED LEARNING AND TRAINING

D M Laurillard

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The Role of Computers in Learning and Training

For some years now there has been a fundamental debate about the role of computers in education, and it is still continuing. The question is, who should have control, the student, or the computer? Control may be exercised over choice of content, sequencing, instructional strategy, or form of presentation - any or all of these; and the balance of control can be entirely with the student, entirely with the computer, or shared. The debate is important for both computer based learning (CBL) and computer based training (CBT), as student control and program control implications for the type of outcome expected.

The main reason for distinguishing between learning and training is that they take place in different contexts. The learning of a topic at school or college takes place in the context of learning about other related topics and is not closely associated with the learner's real world activities. Training is often isolated from other training topics, even related ones, but is usually related to other tasks, and is always close to a real activity. A trainee would expect to relate the failure of a component to the task of repairing it, because that is what the job entails, whereas a student might relate it to the structure of the material, because they are meant to understand why it fails, not how to repair it. This kind of intuitively apparent difference between the two is suggestive of an underlying difference in the nature of cognitive processing required, and hence in the form of teaching that is appropriate.

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Styles of CBL and CBI

D.M. Laurillard

Abstract

The paper discusses styles of CBL and CBI in terms of their fundamental educational characteristics, such as the balance of control between program and learner, and the kinds of learning activity they induce. Learning and training are not considered to be intrinsically different in practice, and styles such as drill-and-practice, tutorial, simulation and modelling are discussed with reference to both. Current implementations of these are described together with a critique of their advantages and disadvantages. Finally the paper discusses the likely educational potential of the new media, and suggests an appropriate model for courseware development.

The dichotomy can be carried through to the role of the computer in training as being to allow drill and practice to criterion performance level, and in learning as allowing exploration through simulation. In fact, of course, it is a false dichotomy. The process of learning, as it is practised in most educational institutions, is very far from the loftier ideals of a self-directed exploration of knowledge, being largely confined to concept classification and rule-using (Merrill 1981), both of which are amenable to the explicit requirements of objectives and criterion performance definitions. All educationalists are agreed that learning must be meaningful, and whether or not this is achieved in the schools, it is acknowledged to be fundamental to any successful instructional strategy (Winn 1981, Merrill 1981, McCann 1981). And training can aspire to no less a goal. If a task is meaningful, then it can be learned efficiently and will not be forgotten so easily. Learning and training are de facto similar, therefore, and effective training requires the same form of instructional strategy as effective learning.

The requirement for meaningfulness is central to the debate about the balance of control. In deciding who should have control, we have to consider whether criterion performance alone is sufficient to establish effective learning, or whether a theoretical description of cognitive processing should guide the design of the instructional strategy. If the program has control, then we must assume that criterion performance is sufficient to ensure mastery. But it is possible for a student to achieve a criterion performance without having understood what they are doing. If this happens, then in learning and training alike, what has been learned may be soon forgotten. An instructional strategy must attempt to engage the learner in "meaningful cognitive processing" (McCann, 1981, p 135). If

the program is to shoulder the responsibility for this, then it must be built on the basis of a clearly defined instructional strategy. If it is to be left to the learner to direct their own learning activities, and to judge when mastery has been achieved, then we may find we expect too much. This is a key issue in the design of CBL and CBT, and will emerge throughout the subsequent discussion.

The relation between objectives and mode of presentation

It is intuitively obvious that for certain kinds of learning objective, certain modes of presentation will be more appropriate than others. For this reason, there is often an expectation among teachers and trainers that there should be clear guidelines coming from educationalists as to what kinds of medium or mode of presentation should be used for any given objective. This would obviously be helpful in deciding on the appropriate style of CBL or CBT to use, so let us consider the nature of this relationship.

The expectation of a relationship occurs because teachers and trainers understand that different kinds of learning and outcome require different kinds of cognitive processing or forms of student activity. Cognitive processing is influenced, in turn, by the presentation, eg. the kinds of instructions given, the kinds of learning activities encouraged (Hartley, 1981). To examine the two parts of this relationship, we consider first the various modes of CBL and CBT, and what level of activity they encourage. Secondly, we shall consider what kinds of cognitive processing are required by the objectives of learning and training, and how these are met by different modes of presentation.

The modes of CBL that are most prevalent are 'drill and practice', 'tutorial', 'simulation' and 'modelling'. In their pure forms, they comprise specfic kinds of learner activity:

Drill and practice - presents a graded sequence of exercises, giving feedback in the form of correct answers.

Tutorial - presents a teaching sequence followed by a test with feedback in the form of hints on further teaching.

Simulation - provides a menu of options which allows the student to 'operate' a system, specified by a model in the program, and to see the results of his operations.

Modelling - provides an environment (or data) within which the student can develop his own models or descriptions and test their validity in that environment.

The balance of control between program and student is different in each of the above modes. Drill and practice and the tutorial programs offer the student little or no control over either sequencing (the order in which topics are presented) or instructional strategy (when to repeat an exercise, when to refer to remedial teaching, etc.). Simulation and modelling offer the student total control within the limitations of the particular model or environment because these modes do not attempt to teach the student. Instead they provide an environment within which they can learn.

The sophistication of program control can vary greatly from those programs which embody a fixed instructional strategy to those that are 'adaptive'. Adaptive teaching programs keep the debate over the balance of control active. The style of program that always controls the student's learning is regarded with suspicion - as was programmed learning - because it is inevitably inefficient for the many students for whom the particular instructional strategy chosen is appropriate. Designers have been attracted to the greater freedom of simulation and modelling which give the student the responsibility of controlling what they do and in what order. However, studies of students' performance under conditions of learner control and program control, began to suggest that students were not, after all, very expert at managing their own strategy, and performance was less good and less efficient under this condition (Fry, 1972) This lent support to those designers who were exploring more sophisticated forms of program control, and has led to the current developments in adaptive teaching programs (O'Shea 1979, Hartley 1973). These programs use information processing results to assist the design of a knowledge base and the procedure by which it can be updated. This means that a program can learn about a student from their performance, and depending on its complexity, will be able to generate exercises tailored to the student's particular problem. Quite apart from the advanced programming techniques this requires, it is also necessary for the program designer to have a detailed understanding of the nature of students' misconceptions in the subject, and some experience of how to correct these. This must itself be researched before it can be programmed in the form of a knowledge base and generative procedure, as required by an adaptive program.

With the possibility of more sophisticated forms of program control available, the debate continues over whether this style of CBL is or is not preferable to learner control. In fact the earlier work, although suggestive of students' incapability of directing their own learning effectively, was never conclusive. The results obtained could have been accounted for by the students' lack of experience with this kind of material, which was used under very bizarre experimental conditions, and by the fact that the material itself was in any case over-structured. (Fry 1972). More recent studies have shown that, under the right conditions, the learner control format is more effective than program control (eg. Hartley, 1981).

The kind of learning activity encouraged by the different modes of CBL depends, therefore, upon the way control is implemented; it is not a simple relationship. We now consider to what extent it is possible to associate the various styles with particular learning objectives.

Learning and training together encompass a wide range of possible objectives, but to simplify the discussion, we can reduce these to three key types that should serve to describe the majority of such activities: learning to carry out a procedure, to use a concept, to understand a system. Examples could be learning Fourier Analysis, or how to carry out a fault-finding procedure, using the concept of 'internal energy' or of 'working capital'; understanding the structure of an atom, or a word-processing system. The question is, to what extent do these different objectives require different forms of learner activity?

To learn to carry out a procedure, a student must be able to see what it is meant to accomplish, must go through each stage of the procedure separately making sure that each is performed correctly internally, and must go through the whole procedure to ensure that each stage is properly integrated. The learner requires the presentation of the correct form, repeated practice, knowledge of mistakes and the opportunity to concentrate on a whole or a part of the procedure. The simple drill and practice instructional strategy (such as that followed by TICCIT, see below) would be the obvious mode of presentation, since it provides all this, but it may not be enough. Suppose the learner is trying to learn the procedure for inserting a paragraph into a text on a word processing system. The procedure will make no sense unless they understand the concept of a file and have a mental picture corresponding to a paragraph being moved from one text file to another. The simple mechanism of drill and practice, while providing much of what is required for this kind of objective, is not a sufficiently specific description, therefore. The presentation of the rules, through general statements or examples of instances, must be carefully designed in such a way that each stage is meaningful to the student. If it is nonsensical, it becomes more difficult to learn and to remember.

Concept learning is traditionally regarded as requiring the student to discriminate essential properties from a series of instances and non-instances (Gagne 1977, Bruner 1956) ideal for a CBL tutorial. Unfortunately, the concepts which abound in adult learning are usually highly abstract and much more complex than 'red circles' and suchlike. When students are rigorously tested for their understanding of high level concepts such as 'gravitational force', 'commodity price', 'oligopoly', results show that there are many mistakes that indicate a lack of relational complexity (Watts and Zylbersztajn,

1981; Dahlgren and Marton, 1978; Taylor et al, 1981). For example, 'price' will be seen by some learners as being simply a property of the commodity, and by others in more complex terms as expressing a relationship between supply and demand. Similarly, concepts such as 'force' require students to make counter-intuitive interpretations of physical events, which definitional presentations do nothing to assist. A tutorial instruction strategy is therefore underspecified as a way of encouraging the right kind of cognitive activities. If concepts involve relations, then a simulation which actively confronts students with those relations is a more appropriate mode of presentation. To understand a system and how it operates, a learner will certainly benefit from controlling a computer simulation of it. But as Bork has shown (Bork, 1980), this can be a very inefficient way of learning if there is no guidance of any kind. Again a hybrid form of simulation plus tutorial is preferable.

It is impossible to discriminate between such high level objectives as procedure learning, concept learning and understanding a system, from the point of view of what CBL style is most appropriate. They all require practice, and feedback, and guidance, and freedom to explore.

The ideas discussed in this section have all been embodied in practical CBL developments in different ways. Four of the principal current styles of CBL are discussed in the next section, none of which correspond to a pure form of the modes described above, but which together illustrate the range of different modes of presentation currently available to CBL.

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Styles of computer-based learning and training

Computer assisted instruction was initiated in the US several years before it was used in the UK. For this reason, the US projects which have survived are now well-established and have had time to refine their various styles of instructional strategy. Each of the four styles discussed below have been implemented in both education and training. Typically, they have originated in the US, but several UK projects have also adopted these ideas and in some cases have developed them further.

(a) TICCIT (Time-Shared Interactive Computer-Controlled Information Television)

The TICCIT system embodies a combination of drill and practice, and tutorial styles.[1] The instructional strategy is built into the system and organises the statement of the 'rule', an 'example' of it, and the means to 'practice' it. The practice phase tests the student on the application of a rule to a particular example (it could be: Is this an instance of the concept 'force'?), the student inputs an answer from a special keyboard, and the feedback given may include an explanation or a hint if the answer is wrong. The presentation uses only still frames with words and graphics. The student has maximal control over what is available on the system - they can control the sequence of topics by choosing from a menu of the list of contents of a lesson, they can control instructional strategy by selecting any number of example and practice frames (at chosen levels of easy or hard), and when they move to a testing sequence, they can choose whether or not to accept the advice that they have or have not mastered the topic. Advice is built into the system in two ways. The author may specify what counts as an acceptable performance on a test, and the student will be advised on whether they have achieved this; secondly the author can program 'advice' frames that will suggest the student try a harder example, or a more advanced rule The student is never controlled by the program. 11

[1] For a fuller description of the project see Merrill 1980

The system is not adaptive, in anything other than a trivial sense, ie. it monitors performance and offers advice on the basis of this, but does not 'learn' about the student, or adopt an instructional model tailored to the individual. The student has full control, therefore, and Merrill has demonstrated that on this system, students who are given the freedom to decide how many practice and example frames they need to achieve mastery do as well as or better than students without this freedom (Merrill, 1980).

The description of instructional strategy used so far has concerned the selection from available content. What TICCIT does not offer to the students is any choice of how they interact with that content. For example, the student could choose to see a frame showing an example of the concept 'force', but cannot choose to see what happens if you vary the force. Rothkopf has invoked the term 'mathemogenic' to describe activities that 'give birth to learning' (Rothkopf, 1965) - something that all educational materials must attempt to encourage. The limitation of the TICCIT format is they do not encourage some of the most important mathemagenic activities such as hypothesis-testing, 'What would happen if.....', looking for analogies with known concepts or systems etc. This may be a direct result of their decision to serve the existing curricula which, as they discovered limit their objectives to the "concept classification' or rule-using level" (Ibid p88). The system is impressive in the degree of student control it allows, but does not encourage the learner to elaborate what they are learning in a way that will make it meaningful and therefore durable.

(b) Educational Technology Center, Irvine.

Professor Bork and his team at Irvine, California have developed a range of teaching materials mainly in basic Maths and Science, which embody both

tutorial and simulation styles of CBL. The tutorial style contrasts with that of TICCIT in that although the students can choose what content to study from a similar menu of choices, they have no control over the instructional strategy, which is built into the program. The tutorials are based around 'quizzes' which are tests in which the learning function is regarded as equally important. The student is given the option of going through a help sequence, which explains the topic, and is then given a quiz which will include help and hints if answers are wrong. The approach to concept learning is importantly different from TICCIT because instead of allowing the student to choose to see examples of a concept, in Bork's tutorial, the student will be given several program-generated instances and non-instances and asked to identify whether or not each one is an instance of the concept (Bork, 1980). The strategy is called 'concealed multiple choice.'

The approach to procedure learning acknowledges the fact that in order to carry out a procedure successfully, it is necessary to have an understanding of each stage. The method is interactive and is designed to lead the student to discover, for example, a derivation of a theorem. The method inevitably comes closer to being a Socratic dialogue, however, as the computer may ask the student what should be done next, but can only correct wrong suggestions, not follow them through. It is a convergent instructional strategy, therefore.

Simulations are used to give students an intuitive grasp of systems - the relations between objects and concepts, and how cause and effect operates in a system. In the context of theoretical physics, it is possible to create elegant simulations based on a well-defined mathematical model, which can give the student the opportunity to vary a range of parameters and generate a potentially infinite set of behaviours of the system. Seeing the results

of successive inputs should allow them to infer an intuitive understanding of how the system operates. For this style of CBL, it is assumed that the system behaves in a rule-governed way which can be understood by becoming familiar with its behaviour. The principle can apply to any system of this type, such as a word-processing system, the planetary system, an electrical circuit etc, which can be modelled in a computer program. Indeed, a survey of CBT in business and industry suggested that simulation is the mode most frequently used (Kearsley et al, 1981). For all these systems, it is perfectly possible for the user to explore them in a totally learner-controlled way, selecting their strategy from a given menu of options, and specifying their own parameter values. Equally it is potentially possible, given this access to the total behaviour of the system, for the user to deduce its underlying model, and by being sufficiently exploratory, to discover all that it can do. It is an attractive idea, but one that is unfamiliar to many people, and the creative possibilities open to the user are often not taken up, (Bork, 1978). Bork has attempted to overcome this problem by providing some guidance in the use of such a simulation (Bork, 1980). The strategy adopted is to display examples of what the system can do, and examples of operations the user might carry out in order to explore it. This form of guidance, rather than control, may be advisable in any similar situation where a student or trainee is attempting to gain familiarity with a system. The point of avoiding program control for this form of objective is that if the user is taken through in a pre-determined sequence the form of cognitive processing encouraged is much more passive. It may also be passive if the user is allowed simply to explore, ie. to discover 'what will happen if.....', because in this case there is no requirement to connect the result with the input. Mathemagenic activities are more likely

to be induced if the user is asked to discover a particular result using the system eg. how to obtain a particular orbit, or a configuration of the circuit that will yield a particular current etc. (Laurillard, 1981). With set goals of this type there is a necessity for the user to connect the input with the output if a successful result is to be achieved, and it is this form of cognitive processing that is necessary to lead to an understanding of how the system operates, hence it is 'mathemagenic'.

There is no attempt to create an adaptive teaching program in Bork's project. The program uses a standard model to respond to student inputs. The degree of program control is considerable in the tutorial mode, less so in the simulation mode, but the latter requires careful guidance if it is to induce learning.

(c) CAISMS (Computer Assisted Study Management System)

Computer Managed Instruction (CMI) is a form of CBL that characteristically embodies a high degree of program control over the instructional strategy. It is premised on the fact that students do not typically study in an efficient and systematic way, and therefore builds a theory of instruction into a program that 'manages' what the student does. The presentation of subject matter may not be done by the computer at all; instead the program directs the student to study part of a text-book and then return to the terminal for a computer-marked test. CAISMS at the University of Illinois is an example of this. Alternatively, the system may route the student through CBL tutorial programs.

The eventual aim of this kind of project is to use adaptive or 'generative' programs that will be capable of adapting the tutorial strategy to the

individual student's learning characteristics (McCann, 1981). Clearly the extent to which this is possible must depend upon the specifity of learning objectives and performance characteristics. Such a program would require an algorithmic description of classes of problems rather than predetermined exercises and possible answers (McCann, 1981). For example, if the designer can define the tutorial strategy in terms of specific performance criteria that the program can test, and in terms of specific condition-action rules (such as 'if student has failed on 3 test questions out of 5 then repeat the last teaching operation') then it is feasible for that strategy to be implemented in algorithmic form in a teaching program (see O'Shea, 1979). This kind of approach allows the designer to test for the presence of different models of student behaviour, eg. the program can be written to deduce from a particular pattern of inputs from a student that they are confusing, say, rational numbers with natural numbers, and on the basis of this can generate further exercises to point out the difference. It is in this sense that these programs are adaptive and can adapt the teaching to individual student characteristics.

The implementation of a tutorial stragegy once it is specified is itself a non-trivial programming problem. The specification of the strategy is even more difficult. The designer must have a full description of the possible ways in which a student can make errors, and must have sufficient experience of teaching the subject to be able to design appropriate tuition to deal with those various misunderstandings. This requires a considerable research programme each time a topic is taught this way - itself no bad thing, of course, but undoubtedly a long-term rather than a short term plan.

This sophisticated level of program control will be difficult to achieve. The case for the superior effectiveness of program control over learner control has not been definitively proven; the case for the greater intractability of the former is apparent.

(d) The LOGO Laboratory, MIT.

The style of CBL that uses the computer as a 'laboratory' is designed to allow the user to practice 'modelling'. The computer program defines an environment, and a series of commands for operating on it. Thus LOGO defines an environment as Euclidean space, and a series of commands that allows the user to operate on an object specifying its position, orientation, and velocity in that space. The expectation is that students will be able to use hypothesis - testing to discover how this environment is governed by a system of laws, in much the same way as a scientist explores the real world. (Wildman, 1981). A fundamental principle is "to construct computational environments which embody physics in such a way that students exploring those environments teach themselves the physics" (di Sessa, 1980, p72). The program exercises no control over the learner, it embodies a complete environment together with all the possible actions in that environment. The student left alone to work on this can work in a pure discovery learning mode, but what precisely does this mean in terms of the mathemagenic activities induced?

The same issue occurs in a different kind of modelling environment, offered by the STATS package at the University of Leeds. This is a simulation language that provides the student with everything they need to explore the operation of statistical methods: sets of data, commands to merge or edit data sets, commands to perform any kind of statistical sampling, or

tests, or to display data in various forms, or to carry out arithmetical operations. Again the package offers complete freedom to the learner who again must act rather like a scientist, and "formulate and sequence his commands and test the output against his intentions" (Hartley, 1981, p111). The mathemagenic activities induced by such programs ought to be impressive precisely because of this freedom. When the learner is in control, each step of the process is likely to be meaningful to them, and the feedback obtained will tell them whether or not they are closer to their intended goal, and, if not, force them to think about how they might achieve this - this formulation of the learning process has a lot in common with classical formulations of scientific method. There is a problem with this, however. Students and trainees are not typically called upon to act 'like scientists' in an educational context. At home or at play, perhaps, in pursuing a hobby or mending the hi-fi, they may well adapt to the role of 'scientist', but they do not expect it to happen in an educational context. This means that they are not practised at discovery or hypothesis-testing strategies and may not carry them out efficiently. As Howe and Ross point out, the mechanisms to be learnt in order to operate LOGO are themselves formidable, and the student needs help, for example in the form of work-sheets, in using them to make discoveries in mathematics (Howe and Ross, 1981). Similarly, Hartley uses work-sheets to guide students towards the concepts implicit in the STATS simulation package.

Providing a modelling environment for a learner to work in is an attractive educational idea, and it may be that if only it were more familiar to students, they would quickly master this type of learning and be able to do it efficiently. Learner control over the presentation of content is a different problem from that debated over the instructional strategy. At

present, the more common experience seems to be that learners need guidance in the way they confront the content, in both simulation and modelling programs.

What should be clear from this section is that none of the four modes of CBL are typically implemented in their pure form. This combination of styles still does not establish any one preferable style, however, as none of the implementations have overcome all the problems of where control should lie, and of how to induce the full range of mathemagenic activities.

New media - new styles?

The new media that are now becoming available to computer-based learning systems bring a new dimension to the mode of learning they can offer. The advent of media such as teletext and interactive video brings the idea of the data-base resource into the realm of CBL. This has been limited until recently by the type of information stored on data-baseis, and by the computer storage capacity required. Teletext attracts a wide range of information being displayed in both alphanumeric and graphics format, and video-discs have the capacity to store both still-frame and motion-picture sequences. These media open up the possibility of student access to encyclopeadic quantities of information, made easily accessible by computer control. Teletext offers nothing new in the presentation of information, but the controls of a video-disc player offer a new way of interacting with visual information, such as stop-frame, slow and fast forward, slow reverse, together with the possibility of accompanying audio. These capabilities can considerably enhance the quality of the presentation of content in a CBL system,[1] (see for example , Zollman and Fuller, 1982).

[1] The interface between a micro-computer and a video-disc or video-cassette player is technically straightforward, and interface boards with accompanying software can now be bought off the shelf. See Paper 5.

The availability of this kind of data-base as a resource does offer a genuinely different style of CBL, and one that will renew the debate over who should control instructional strategy. Should the computer be used to guide the user through the information, using the video to enhance a tutorial presentation, or should it be used simply to provide a description of and easy access to this potentially vast data-bank? Conventional data-base systems have spawned a number of projects to investigate how their operation can be made intelligible to naive users (see for example Morton, et al, 1979, and HumRRO, 1982). Adopting the correct strategy to access information appropriate to a particular goal is a skill that users do not find natural. The design of the data-base interface is, therefore, critical. If, for example, the description of the information does not correspond to the user's formulation, it could be impossible to find.

Using this kind of system in a learning or training environment has inherent advantages and disadvantages. Research studies have shown that students may have different preferred orderings of material to be learned - some prefer to move step by step building up from descriptions of details to general principles; some prefer the reverse, to begin with the general principles and to learn about the details later (Pask, 1976).
Free access to a data-base that provides both types of information would allow students to adopt either strategy, or even a mixture of the two. That could be an advantage, and provide more efficient learning. The disadvantages could appear when it becomes apparent that a learner does not know what is required to learn a topic. Such a problem can occur, for example, if trainee pilots are given free access to a video-disc containing information on all parts and subsystems of an aeroplane's controls. Not knowing which

aspects are essential for them to know, they may tend to access several sequences of information that are unnecessary, and therefore find the method very inefficient. Again, it is clear that the design of the human-computer interface is crucial for its effective use.

The new media have the potential to provide genuinely innovatory forms of learning, but only if sufficient attention is given to the effective design of the interface, in this case the courseware, which is discussed in the next section.

Courseware production

As computer-based learning systems become cheaper, the hardware proliferates and becomes a common accessory to every institution and department. Courseware production has never kept pace with the expansion. A great deal of educational courseware has been produced, but it suffers from two problems: courseware developed for one machine does not easily transfer to a different one; and courseware that is not very well designed does not easily transfer to another institution. The former problem is gradually disappearing as microcomputers and their software packages become more compatible. The second problem shows no signs of improving.

High quality courseware is expensive and difficult. The lessons of the experiments with programmed learning led some projects to conclude that the burden of teaching design was too great, and it is preferable to use computers to direct and manage student learning from conventional materials such as text-books (McCann, 1981). The solution adopted currently by the Microelectronics Education Programme in the UK, is to distribute the responsibility for courseware production as widely as possible, and encourage

teachers to develop their own. This is a relatively inexpensive way of producing a lot of material. An alternative model, adopted by Alfred Bork and his colleagues, is the ad hoc team approach: courseware is designed by a core group of CAL designers and educationists supplemented by subject matter experts and experienced teachers who are brought in according to the subject matter of the package under development. The design team produces a detailed outline which is then put into production by a graphics designer and a computer programmer. (Bork, 1980). This model is expensive in designer time and, being centralised rather than distributed, can only produce a limited amount of material at a time.

A fully adequate development procedure for the production of any educational or training materials will include the following steps.

task analysis - making use of existing teaching or training experience to assess typical learner problems, studying the expert performance on the task itself to assess appropriate objectives.

pedagogic design - on the basis of teaching experience and the chosen instructional strategy, design the CBL or CBT implementation.

production - hand over detailed instructions to production team, making use of their expertise to enhance presentation.

evaluation - run pilot tests with a small sample of the population to allow changes before the production is finalised

These are the minimum requirements for a professional product, and virtually impossible for an individual working alone to carry out. The team approach acknowledges the complexity of the process and provides the opportunity for pedagogic design to be contributed by a wider range of experience and ideas than one person could provide. The course team model has been successful for example, in producing high quality educational material in a multi-media form at the Open University. CBL and CBT has rarely been developed in this way, and the more prevalent cottage industry model has not been acknowledged as a success.

Studies of CBI show that instructional gains are higher and time is shorter, (States, 1980; Kulik et al, 1980) but differences are small. If CBL and CBT are to become established as efficient methods of learning, then the general standard of courseware has to be much higher, even if the quantity produced is lower, the quality is intimately linked to the model of courseware production, and the case for experimenting with a different one must now be a strong one.

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